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EINSTein Model Validation

OPERATIONS RESEARCH CENTER OF EXCELLENCE
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August 2002

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Abstract

The use of Agent Based Models (ABM) to simulate behaviors in combat is gaining increasing recognition and interest across the Operations Research community of both the Marine Corps and now the Army. This paper presents our attempt to "validate" EINSTein (Enhanced ISAAC Neural Simulation Tool) by comparing its outputs to those of another well-known combat simulation model, JANUS. The experiment first establishes the combat effectiveness of EINSTein entities executing a National Training Center (NTC)-type scenario. The scenario is designed to replicate one armored company of 14 "friendly" tanks versus a similar size force of 14 "enemy" main battle tanks. We allowed one set of "friendly" entities to gain knowledge, or "learn," by using the genetic algorithm incorporated in EINSTein. Another set of friendly entities was not allowed to "learn." For both cases, we recorded both the combat results of the EINSTein simulations and the entity actions. These observed actions were programmed into JANUS. For each instance, we compared the combat effectiveness resulting from JANUS to those obtained from EINSTein. The hypothesis of the experiment is that the entities that were allowed to "learn" will have noticeably different behavior and have a significantly better loss-exchange ratio in both EINSTein and JANUS. The paper presents the findings of our analysis and suggests further research areas for using ABM's.

About the Author(s)

Major Randall Klingaman is an Assistant Professor in the Department of Systems Engineering at the United States Military Academy (USMA) at West Point, New York. MAJ Klingaman graduated with a MS degree in Industrial Engineering from the Georgia Institute of Technology in 2000 and a BS in Chemistry from USMA in 1991. Major Klingaman has served as an Infantry Officer for 11 years in the U.S. Army and is currently serving in the U.S. Army as a Functional Area 49, Operations Research officer. Major Sander's research interests include complex adaptive systems, agent based modeling, and production operations engineering.

Acknowledgements

This work is indebted to previous work done in concert with Project Albert, in particular to work done by Dr Andy Illachinski of the Center for Naval Analysis who created the model that we utilized. We would also like to recognize MAJ Suzanne Delong and Mr. Paul West for their contribution to our understanding of the JANUS combat model.

Table of Contents

Chapter 1: Briefing Slides for MORS Symposium

The following slides represent the briefing that was given at the MORS Symposium in June 2002 at Ft. Leavenworth, KS.

EINSTein Validation Experiment

MAJ Randall Klingaman
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U.S. Military Academy
West Point, NY

Agenda

- Purpose
- Design of Experiment
- EINSTein Experiment and Results
- JANUS Experiment and Results
- Comparison of Results
- Validation Issues
- Conclusions
- Future Work
- Implications to Future Modeling and Simulation
- Questions

Purpose of Research

- **To find out if an ABM scenario can be translated into JANUS and produce similar outcomes**
  - ➢ Determine strengths and weaknesses of each model
  - ➢ Determine areas for improvement
  - ➢ Determine possibilities for transfer of processes
  - ➢ Modeling issues and concerns
- **To "validate" Agent Based Model (ABM) via comparison to a proven combat simulation model - JANUS, using a National Training Center (NTC) scenario**
  - ➢ Are outcomes similar
  - ➢ Are observed behaviors similar
  - ➢ Are results believable

Design of Experiment
(1 of 2)

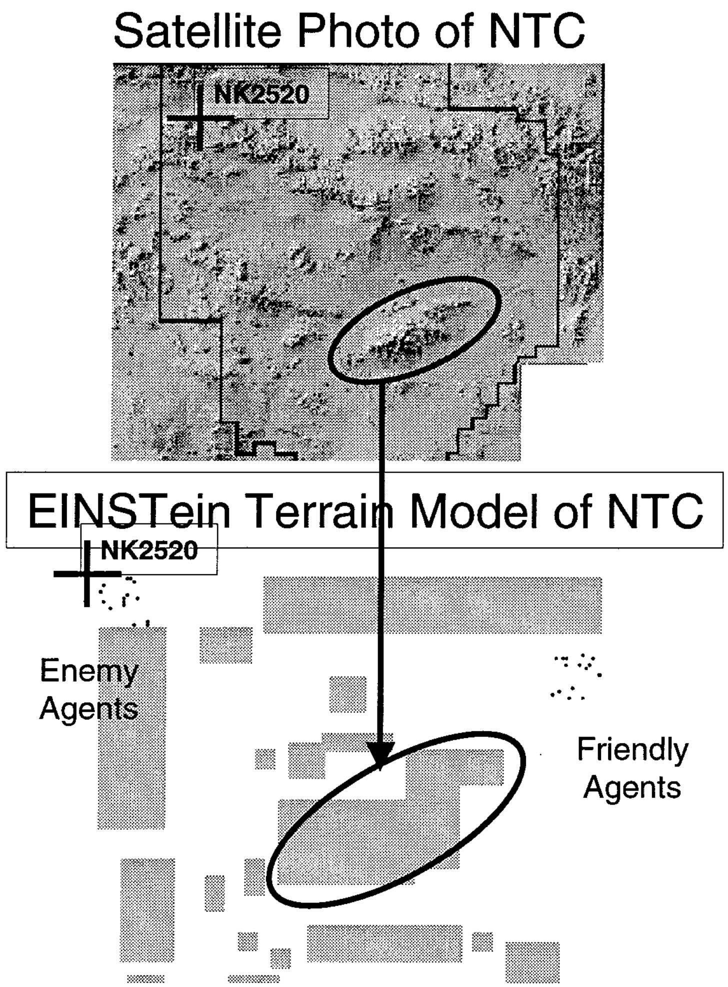
- **Compare LER results for a 2^2 – Full Factorial Experimental Design:**
  - Factor A: EINSTein ABM, Janus
  - Factor B: Agents w/o learning, Agents w/ learning
- **Response variable is Loss Exchange Ration (LER)**
  - Common to both models
  - Commonly used metric in combat models
- **H_o: LER of initial agents and agents with "learning" in ABM will follow similar outcomes when transferred to a "traditional" combat simulation**

Design of Experiment
(2 of 2)

- **EINSTein's genetic algorithm enables agent "learning"**
- **Captured agent movements for input into JANUS**
  - Company Centers of Mass
- **Scenario chosen is 14 M1A2s against 14 T-80s in a Movement to Contact (MTC) mission**
- **Agents (& JANUS) entities have "matching" capabilities:**
  - Speed
  - Communications Ranges
  - Sensor Ranges
  - Engagement Capabilities

EINSTein Experiment

Convert the Terrain



- The NTC is reasonably close to EINSTein's "tabletop" terrain
- 30 km x 30 km square of NTC covering major force-on-force maneuver areas
- Grid NK2520 upper left corner
- Major terrain features captured as "boxes" in EINSTein
- Scale: 1 km = 5 EINSTein spaces
- 22 impassable squares created; agents can not see or shoot thru

EINSTein Experiment
Create the Agents (1 of 2)

- Maneuver Speed - M1 and T-80 speeds set equal
- Survivability – In EINSTein, 2 hits degrade agent to injured status, 1 additional hit degrades to killed status
- Communication Range - Based on max SINCGARS range (30 km), set to entire EINSTein box for both Blue and Red agents
- Sensor Range - Set to 20 EINSTein spaces for both Blue and Red agents to match JANUS capability
- Weapons Range - M1 and T-80 set equal at 10 EINSTein spaces; EINSTein agents have 1 weapon; based on max range of main gun sabot

EINSTein Experiment

Create the Agents (2 of 2)

- **Single Shot Probability- Based on JANUS P(Hit) of weapon system:**
  - 95% for M1 @ 2000m for SSEH
  - 91% for T80 @ 2000m for SSEH
  - When agent is injured, reduced to 50%
- **Max # of Simultaneously Targetable Enemy - Set to 2 based on ability of Tank Commander and Gunner to track enemy for both Blue and Red**
- **Fratricide- Turned off**
- **Reconstitution- Turned Off**
- **Local Commanders- Not used**

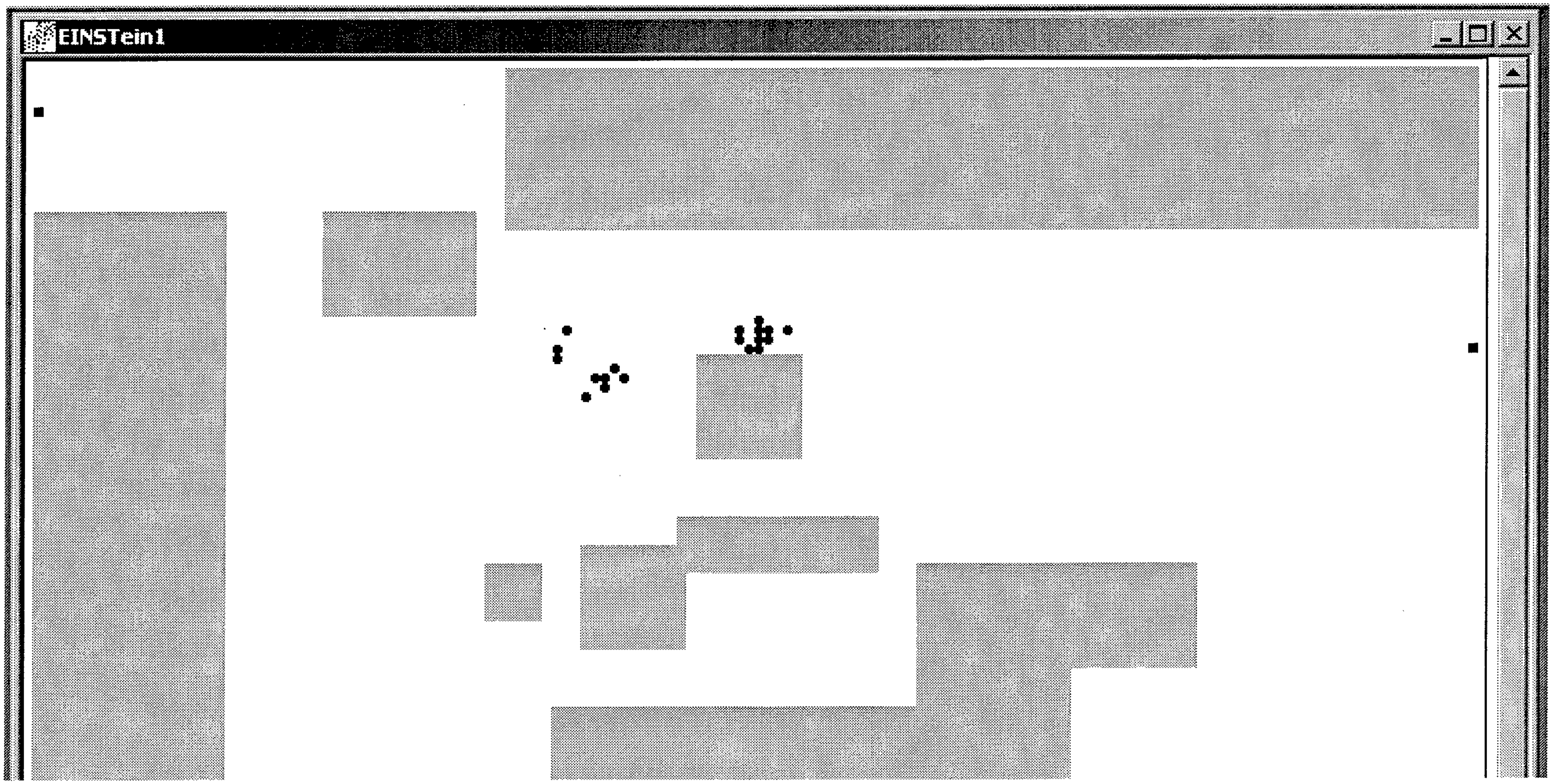
Initial Agent Personality

- **Agent's actions defined by relative values of six-component personality weight vector**
  - ➢ Propensity of alive Blue agent to move towards: alive Blue, alive Red, injured Blue, injured Red, Blue goal, Red goal
  - ➢ Similar vector for injured agents and Red agents
- **Alive agents are weighted to move towards injured enemy first, alive enemy second, and then the enemy flag; Vector = (10, 50, 10, 60, 0, 40)**
- **Injured agents are weighted to move towards alive friendly first, injured friendly second, and then the enemy flag; Vector = (50, 5, 40, 5, 0, 40)**

EINSTein's Genetic Algorithm

- **Allows agents to "learn" via mutations in personality and meta-personality to most closely achieve mission primitive objectives**
- **Mission primitive objectives: Equally set to Maximize Enemy Killed and Maximize Friendly-to-Enemy Survival Ratio**
- **"Learned" Agents exhibit different behavior:**
  - Use terrain to their advantage
  - Will approach enemy more cautiously
  - Formation is tighter when moving and fighting
  - Tend to retreat if outnumbered or wounded

EINSTein Scenario



EINSTein LER Results

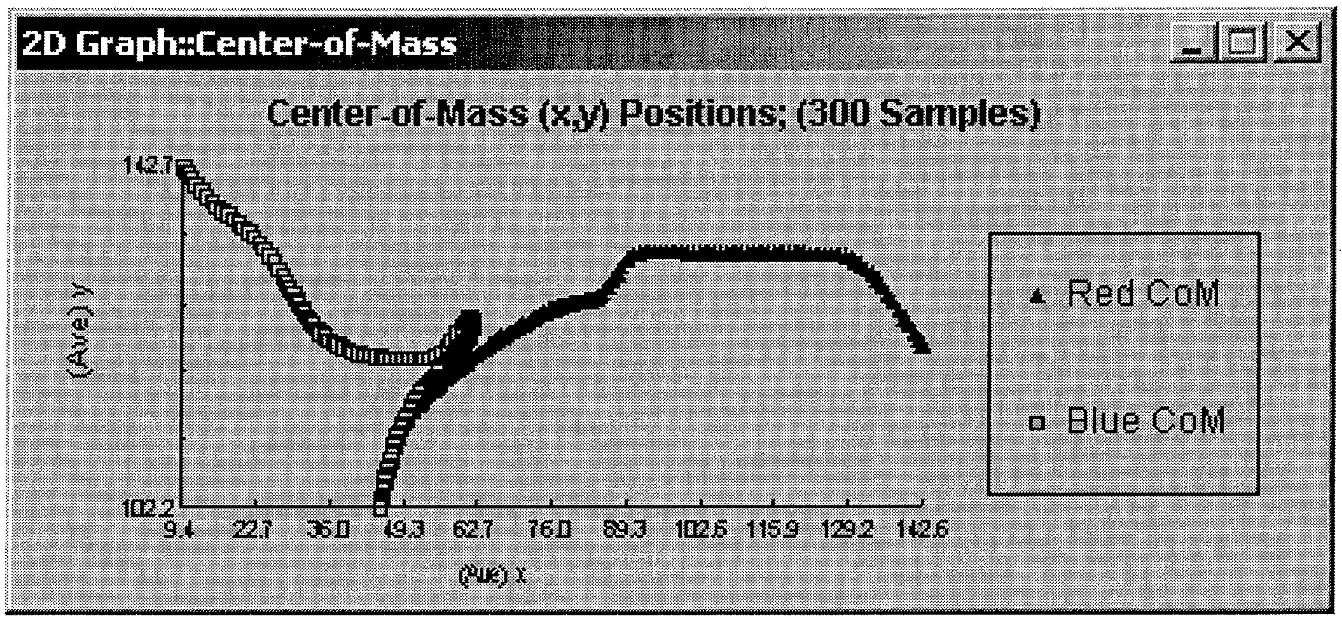
- 300 replications using each type of agent
- Results based on simulation time of 125 time steps at the "crescendo of the battle"

	Mean	Std Dev
Initial Agents-	2.659	1.67
Learned Agents-	2.451	1.29

- Mean LER of EINSTein agents are the same (p-value = 0.055)

JANUS Experiment
Creating the Scenario (1 of 2)

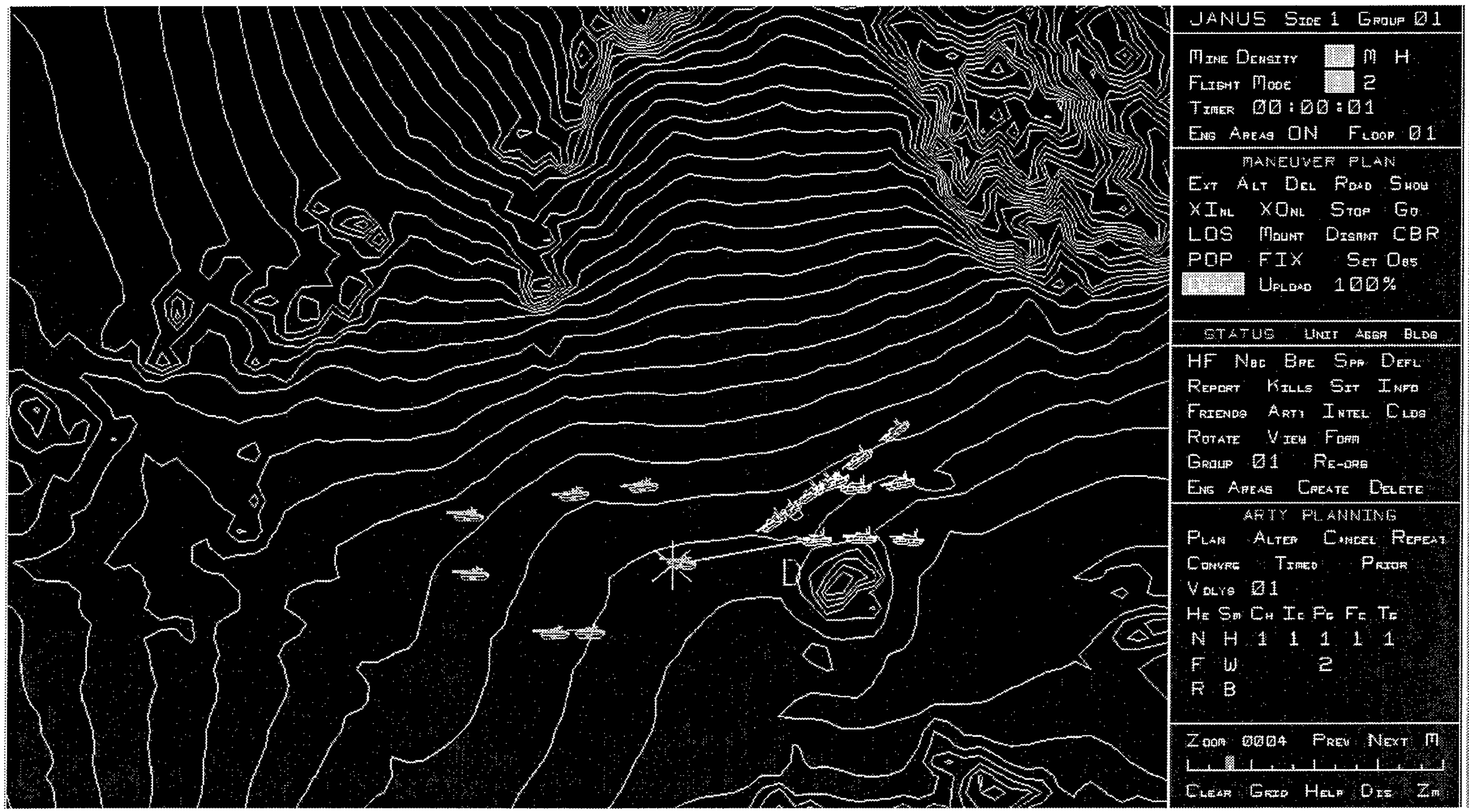
- NTC Terrain file # 951 used
- Center-of-Mass positions of agents used to derive routes in JANUS



JANUS Experiment
Creating the Scenario (2 of 2)

- 14 M1A2s (System # 101) vs. 14 T-80U (System # 102)
- 120mm APDU (Weapon # 19) vs. 125mm AP (Weapon #22)
- P(Hit) Tables and P(Kill) tables taken from Joint Conflict & Tactical Simulation (JCATS) program
- No other battlefield effects modeled
- Central corridor fight centered around Hill 876 (Division Hill)

JANUS Scenario



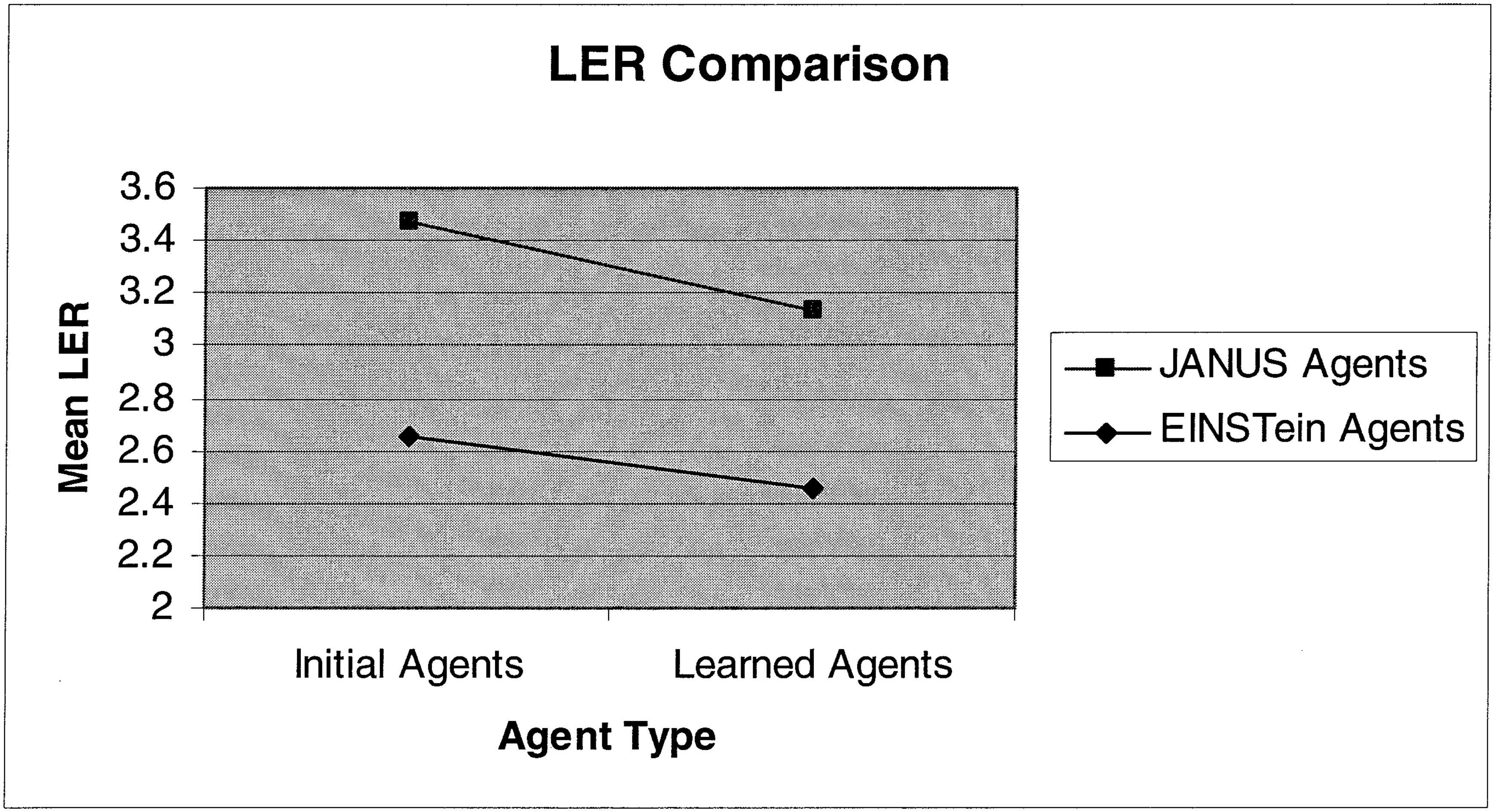
JANUS LER Results

- 30 replications using each route and formation
- Results based on final LER as units converged

	Mean	Std Dev
Initial Agents-	3.47	1.81
Learned Agents-	3.13	0.903

- Mean LER of JANUS combatants are the same (p-value = 0.399)

LER Results Comparison (1 of 2)



LER Results Comparison (2 of 2)

- MINITAB General Linear Model analysis of two factors (agent type and model type) with two levels each (initial/learned and EINSTein/JANUS) indicates only model type affects LER outcome
- Agent Type coefficient = 0.0008 (p-value = 0.989, F=0)
- Model Type coefficient = -0.709 (p-value = 0.000, F=57.3)
- Data in both models does follow similar trends
- Standard deviations of mean LER also decrease from initial agents to "learned" agents in both models

Modeling Issues- EINSTein (1 of 2)

- Lack of elevation in terrain creates unrealistic scenario for transfer to JANUS (always moving at max speed, no inter-visibility lines, etc.)
- Necessary to smooth terrain features so agents have freedom to maneuver
- Inability to model roads and trails due to size
- 150 x 150 battlefield size and size of agent does not accurately correspond to size of vehicles in JANUS
- Combination of survivability and single shot probability does not accurately reflect P(Hit), P(Kill) and posture of engagements in JANUS

Modeling Issues- EINSTein (2 of 2)

- Agents have ability to sense in 360 radius which is not the case in JANUS
- Communications range, weapons range, sensor range always at "best case"
- Single shot probability does not adjust for range
- No other battlefield effects considered (smoke, night engagements, artillery)
- Rate of fire and ammunition re-loads not modeled
- Position output improved to allow for translation into a specific route

Modeling Issues- JANUS

- Inability to allow for decision making of combatants: routes, formation, orientation all pre-set
- No representation of information sharing
- JANUS replications are started/stopped by hand
- Inability to allow “learning” via genetic algorithm
- Lack of mission primitive objective that drives combatant actions
- P(Hit) and P(Kill) tables do not incorporate classified weapons data

Conclusions

- Reject H_o; LER is different based on the model type used; LER similar when based on agent type
- Agents in EINSTein do reasonably portray similarities of combat vehicles
- “Learning,” as portrayed in EINSTein can be transferred into a combat model

Implications for Future Modeling and Simulation

- ABMs need increased fidelity in terms of terrain and weapons performance
- Traditional combat models should incorporate ABM-type decision making and personality traits to allow for more realistic combatant actions
- Traditional combat models should incorporate ABM-type learning to account for experiential learning of combatants and more robust course of action development

Possible Future Work

- Increase size of units being modeled to battalion level
- Account for unit-level commanders and C2
- Account for varying weapons platforms, including the M2 Bradley and BMP
- Account for other battlefield effects artillery, aviation, smoke, etc.
- Model verification

Questions?

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Appendix A: List of Abbreviations

A	
ABM	Agent Based Modeling
E	
EINSTein	Enhanced ISAAC Neural Simulation Tool
N	
NTC	National Training Center

*This table is sorted alphabetically

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